CHAPTER 4

REPAIR SCHEMES AND COSTS

FOR

CUTS IN FLEXIBLE PAVEMENTS

Introduction

Deflection measurements and visual evaluation show that utility cuts ordinarily weaken the adjacent pavement, Figure 4.1. In the thirty-six (36) asphaltic concrete and macadam pavement sites studied in detail, Chapter 2, the damage extended beyond the edge of the cut in all directions for an average distance of 3 feet. Thus, for a typical utility cut excavation of 4 feet by 5 feet, the affected area of pavement was 10 feet by 11 feet. It was also shown, Chapter 2, that to restore the disturbed pavement to its original strength will require, under average conditions, the application of an overlay 1.75 inches thick.

Visual investigation of PCC pavements showed that ordinary cuts in PCC pavements and the pavements surrounding them require no special restoration maintenance when the restoration is carried out in accordance with the City of Cincinnati Specifications of Restoration Standards. Furthermore, from the Finite Element Analysis of Portland Cement Concrete pavements, Chapter 3, the impact of utility cuts on the surrounding pavement and subgrade was found to be acceptable, except in those cases when the cut was placed near a joint at the edge of a slab, or along the curb.

In this chapter, four possible repair schemes with associated costs are described for restoration of asphaltic concrete and macadam pavements.

It should be noted, that presently there are no established procedures to strenghten flexible pavements around poorly restored utility cuts. For estimating the costs involved, the cost of laying a 1.7 inch thick overlay has been used. However it is realized that to remedy a local weakness in a flexible pavement (around a cut), a customary AC overlay may not be totally effective, or even practical. Therefore, the researchers present possible schemes for cost estimates only. The effectiveness of any scheme can only be evaluated by field trials. The details of possible schemes and their cost estimates are presented in the following sections.

Proposed Repair Schemes

All of the repair schemes are designed to restore the pavement to its original strength or capacity. The designs are based on a utility cut opening of 4 feet by 5 feet, assume pavement subgrade damage 3 feet in all directions beyond the edges of the cut, and assume the strength requirement of an additional 1.75 inches of AC over the "standard" AC or macadam pavement. In all the repair schemes, it is assumed the trench has been properly backfilled by the utility contractor. The construction costs used in estimating the cost of the various repair schemes were based on unit prices provided by three independent paving contractors.

Scheme 1 consists of placing an additional 1.75 inch layer of AC over the patch and adjacent pavement, extending laterally a distance of 3 feet to all sides, then extending an additional 1.75 feet on a taper to zero at the original pavement surface. The new pavement surface thus would cover an area of approximately 196 square feet. The estimated cost of this technique, Figure 4.2, is $1,000. This scheme, while likely acceptable strengthwise, is not practical on a 196 square foot overlay because the edges (transition) would be rough and adversely affect ridability.

Scheme 2 is intended for the restoration of a typical 7 inches thick asphaltic concrete pavement. It uses Gilsonite Asphalt which has approximately 50 percent higher tensile strength than ordinary asphalt. Thus replacing a 3.5 inch thick portion of the 7 inch asphalt with Gilsonite Asphalt would not only replace the removed asphalt, but would also provide additional strength equivalent to an 1.75 inches thick overlay on top of the original pavement. The scheme, therefore, consists of removal of 3.5 inches thick portion of the AC pavement over the cut area and 3 feet beyond the cut edges, and replacing the removed material with Gilsonite Asphalt. This will provide increased strength without changing the thickness of the pavement. The estimated average cost using the Gilsonite repair technique, Figure 4.3, is $950.

Scheme 3 is intended for the restoration of asphaltic concrete pavement. It consists of removal of the AC pavement and portion of the subgrade over the cut area and 3 feet beyond the cut edges to a depth of 8.75 inches, followed by placement of an 8.75 inch AC pavement over the entire area of 110 square feet. Average cost using this technique, Figure 4.4, is $1400.

Scheme 4 is intended for the restoration of macadam pavement typically composed of 2 inches thick AC and 8 inches thick base. It consists of increasing the thickness of the AC by 1.75 inches. This is done by removing the pavement and portions of the subgrade over the cut area and 3 feet beyond the cut edges to a depth of 11.75 inches, placement of compacted base course to within 3.75 inches of the finished surface, then placement of 3.75 inches of AC over the entire area of 110 square feet. Average cost of this scheme, Figure

4.5, is $1,000.

The proposed strengthening schemes are conceptual and tentative only but they are believed to be technically effective and constructible. They are presented here for cost estimates. It is recognized that their proof of performance will require actual construction and evaluation.

From the above segments, the cost of the cut repair varies from $950 to $1,400. If the City of Cincinnati permits 6,000 to 10,000 cuts each year, and 35% of these are made in flexible pavements, then the annual cut repair costs may range from $1,995,000 ($950 * 0.35 * 6,000) to $4,900,000 ($1,400 * 0.35 * 10,000).

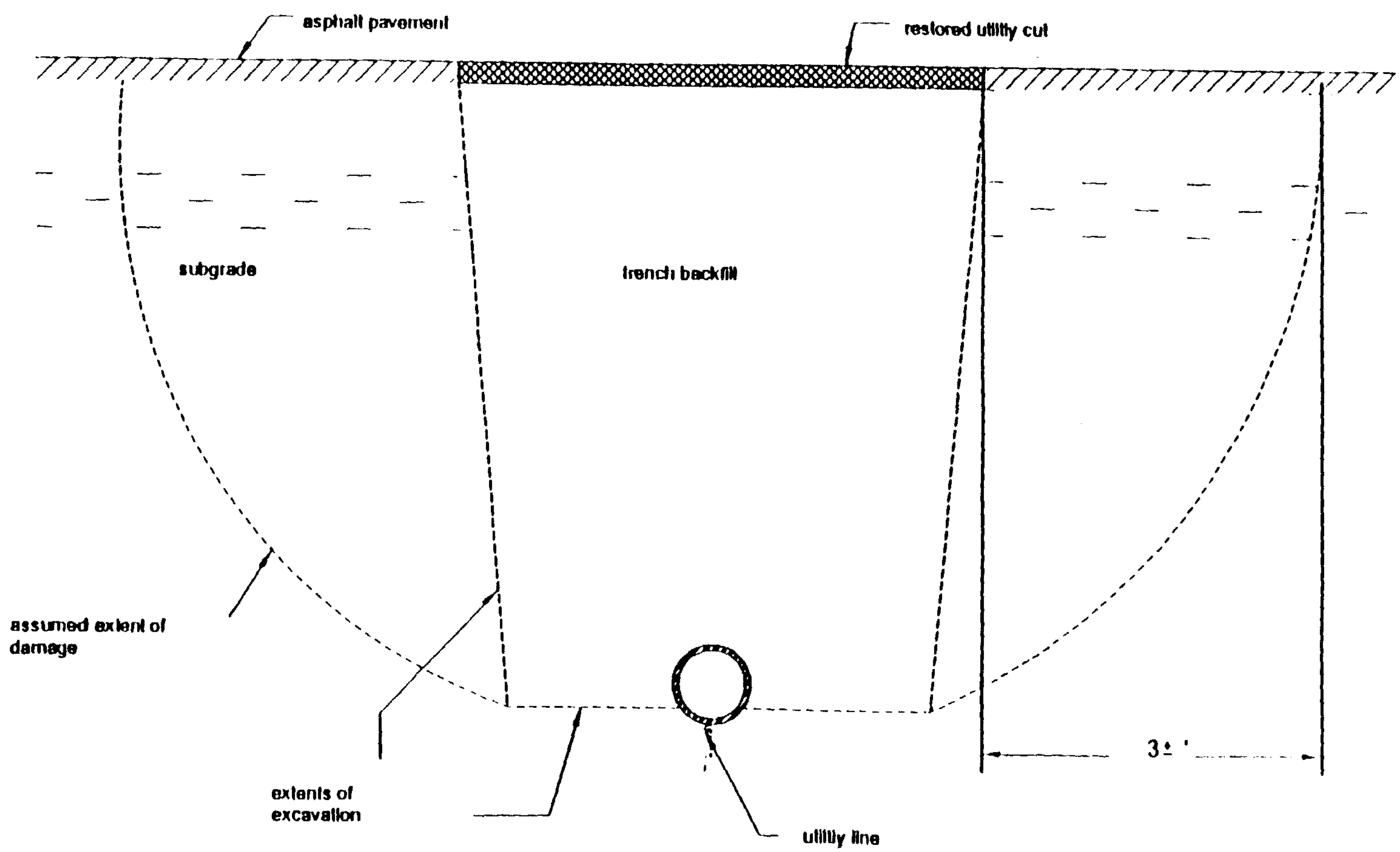

FIG. 4.1. Zones of Weakened Subgrade Due to Utility Cut

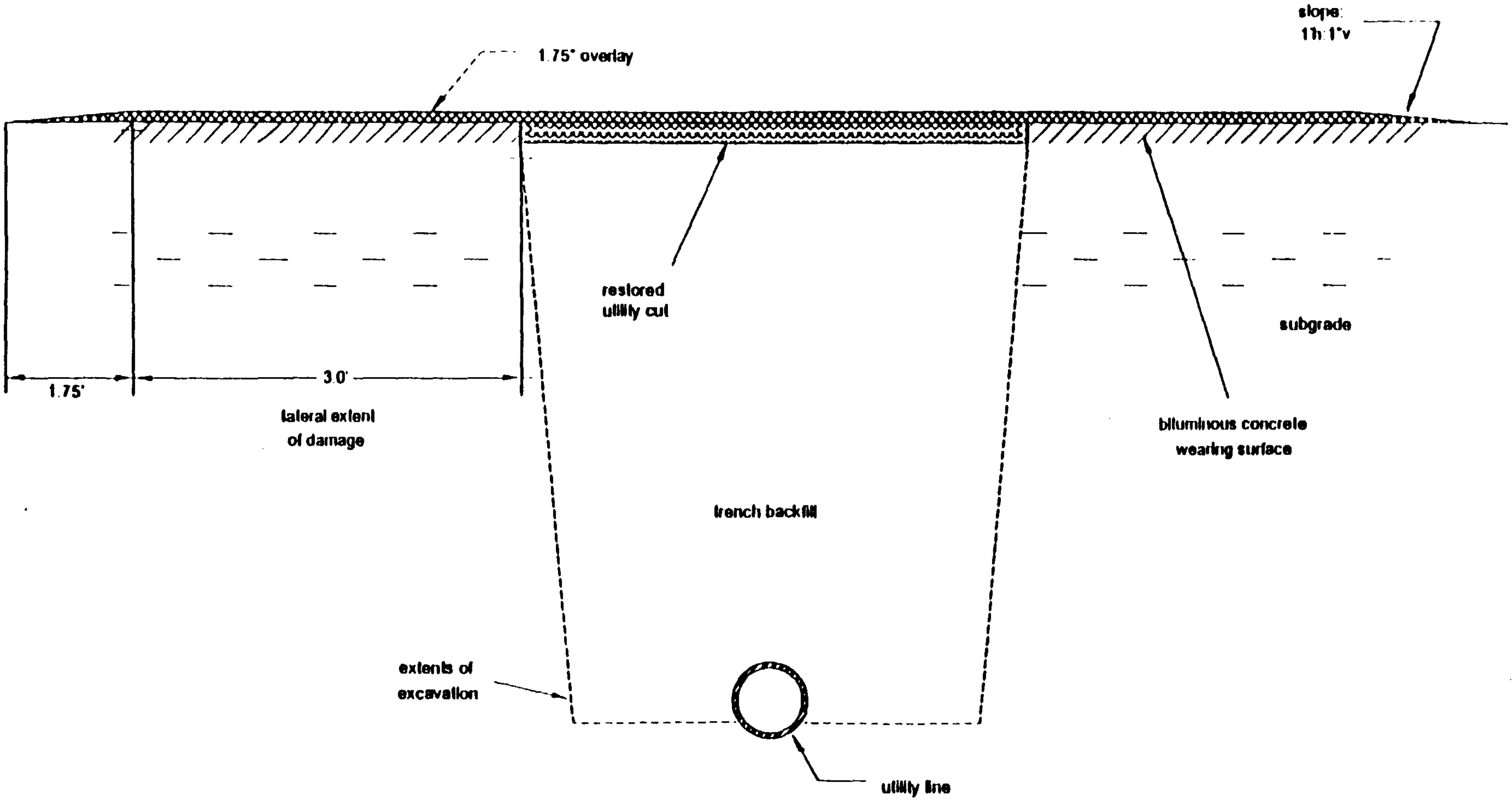

FIG. 4.2. Pavement Strengthened by 1.75 in. AC Overlay - Scheme 1

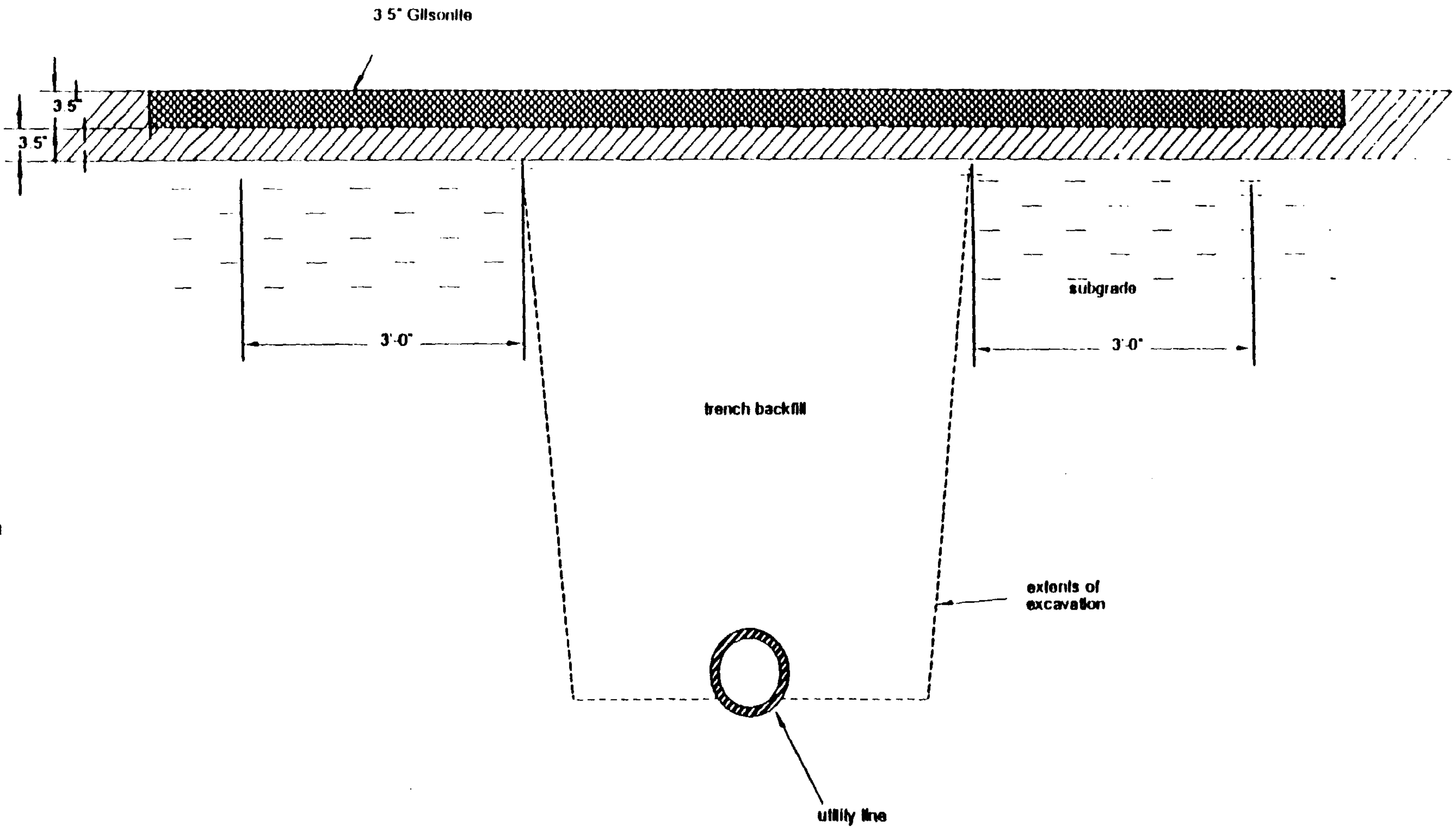

FIG. 4.3. Pavement Strengthening by Replacing a 3.5 in. Thick Portion of AC Pavement with 3.5 in. Thick Gilsonite Asphalt Pad - Scheme 2

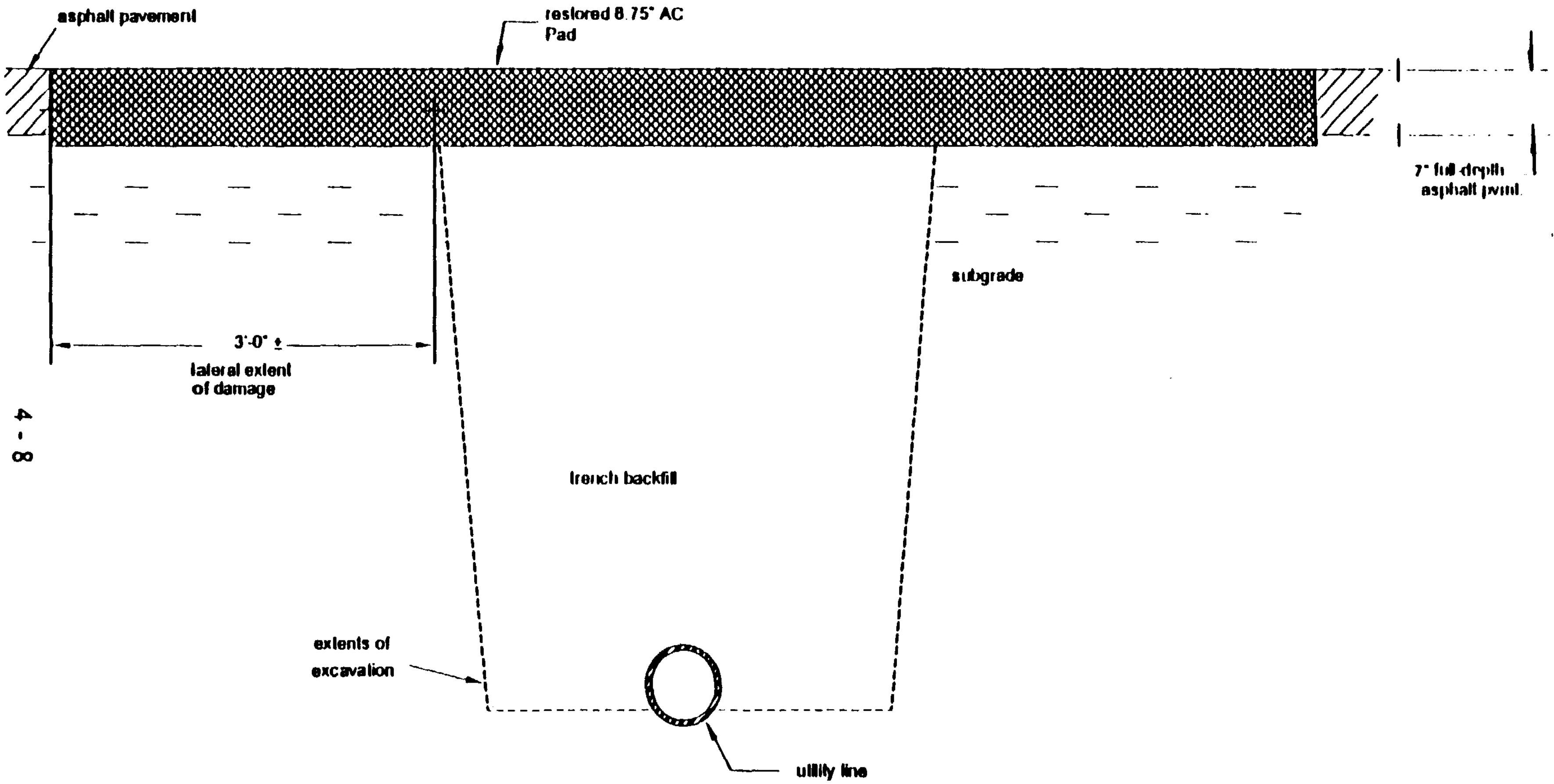

FIG. 4.4. Pavement Strenthening by Replacing the 7 in. Thick AC Pavement with an 8.75 in. AC Pad - Scheme 3

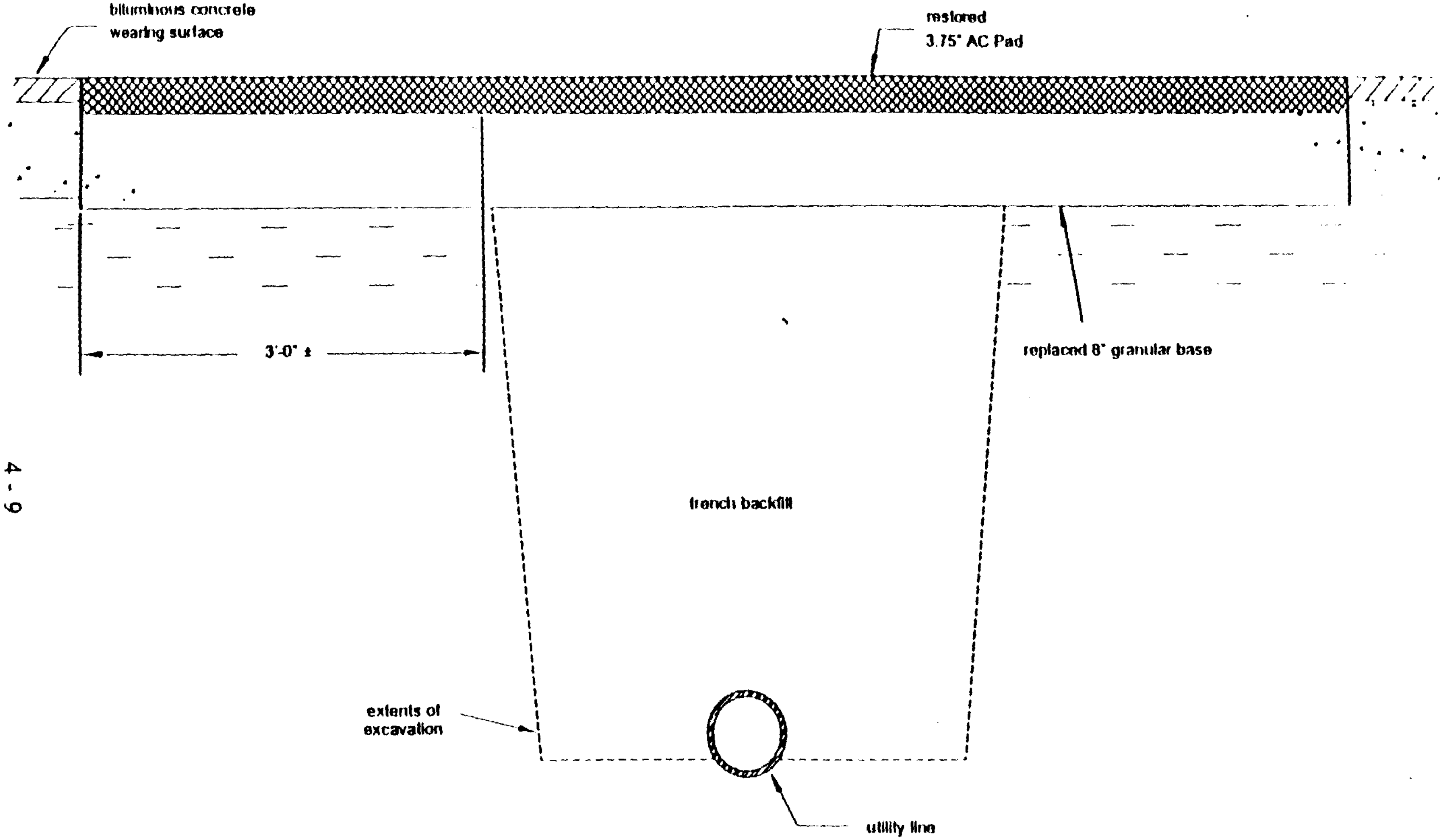

FIG. 4.5. Pavement Strengthening by a Deeper 8 in. Thick Granular Base and 3.75 in. Thick AC Pad - Scheme 4

CHAPTER 5

CONDITION EVALUATION

USING DISTRESS SURVEY

A periodic monitoring of highway pavement for condition evaluation is an essential aspect of a maintenance program. The components of a monitoring program, include (i) specific guidelines to evaluate distresses (in the form of a Distress Manual), and (ii) a procedure to assemble individual distresses into an aggregate index.

The distress manuals developed by the National Research Council's Strategic Highway Research Program (SHRP) (5.1), the U.S. Army Corps of Engineers' Construction Engineering Research Laboratory (CERL) (5.2), and various state agencies (5.3, 5.4) provide specific guidelines for evaluating the severity and extent of distresses on a global level for our Interstate and State Highways. However, when the distresses are localized, as in the case of utility cuts, engineers are required to investigate a small area of the pavement for which no specific guidelines are available.

There is considerable variety in the ways that individual agencies use pavement condition data. The two most common methods are:

(1) Combine attributes in a specific manner to determine a single (aggregate) index.

(2) Use the data in decision trees (disaggregate), to determine condition states, or tabulate the data in the form of a pavement condition matrix.

The first method, aggregating pavement condition data into a single rating index, is a widely used concept to support project and network level decisions in pavement management (5.5).

Typical condition indicators for highway pavements referred to in the literature are Present Serviceability Index (PSI) of AASHTO (5.6), Pavement Condition Index (PCI) of CERL (5.7), Pavement Condition Rating (PCR) of Ohio and Ontario (5.8, 5.9) and Pavement Quality Index (PQI) of Alberta (5.10). Specific guidelines are available to gather the data required for developing any of these indices. These indices assist in evaluating the condition of pavements on a global level for an extended highway segment. In order to assemble individual distresses into a single matrix, several procedures have been used in the past with the deduct points method being the most widely used (5.2, 5.3). However, there are no specific guidelines available for condition evaluation of utility cuts or establishment of a rating index. Engineers have so far relied on their experience for evaluating utility cuts since the condition indicators mentioned above have not been used for localized distress evaluation.

The above discussions call for the development of a Distress Manual and a new rating index for utility cuts.

Distress Manual

The distress manuals developed by SHRP (5.1) and CERL (5.2) encompass all categories of pavements and possible distress types. Unfortunately the manuals currently available do not make a clear distinction between the evaluation of extended pavement sections and utility cuts. Hence a distress manual for utility cuts (5.11), which was a first attempt to list the most predominant distresses in utility cuts, was developed (See Appendix C). The manual considers various types and severity of distresses, but does not consider the extent due to the relatively small area of utility cuts. The manual lists nine types of distresses with their level of severity at (a) low, (b) moderate or (c) high. The distresses listed are:

1. Alligator cracking
2. Edge cracking
3. Transverse cracking
4. Potholes
5. Rutting
6. Ravelling and weathering
7. Pavement drop-off
8. Edge separation
9. Corner breaks

All of the above distresses, except numbers 6, 8 and 9, are applicable also for evaluation of distresses in the vicinity of cuts.

Field Studies

Distress surveys were carried out to identify the type and severity of distresses present in and around utility cuts. Although the Distress Manual provides necessary guidelines, the experience of the engineer or inspector plays a critical role in the survey. This is because the severity of a distress is subjectively assessed as low, moderate or high, as described in the manual. In order to reduce variations in the evaluation of distress conditions, collective judgments of engineers and inspectors were used. The condition data were collected on selected utility cuts in the City of Cincinnati using the Delphi Method.

Data Collection by Delphi Method

The Delphi Method is a spin-off of defense research (5.12). This method extracts expert opinions on items that are subjective and reduces the variation in their responses. The Delphi Method is an iterative procedure characterized by three features: (i) anonymity, (ii) iteration with controlled feedback, and (iii) statistical response. The opinions of the panelists, who respond to a series of questions, remain unknown to one other. After the survey is completed, feedback is provided to each participant regarding the summary results. If there are wide variations in the opinions of the panelists on any item, a new round of survey is performed, based on the results of the previous round. This process is continued until an agreement or near agreement is reached on various items under consideration, or until it becomes evident that no such agreement can be reached.

The panel for Delphi study consisted of four engineers from the Highway Engineering Office and 11 inspectors from the Highway Maintenance Department of the City of Cincinnati. Normally the inspectors from the Maintenance Department are responsible for routine evaluation and inspection of utility cuts. Since the objective of the study was to collect opinions from a wide range of experts, engineers from the Highway Engineering Office were included in the Delphi panel.

The Delphi Method required asking the panelists simple questions as to the type and severity of distresses present in each utility cut. A questionnaire was prepared in the form of an Evaluation Form as shown in Figure 5.1. This form was designed to ask the panelist about the surface profile, type and severity of the existing distresses, overall condition of the cut, and recommended action. One Evaluation Form was used by a panelist for each cut.

In all, 75 cuts in asphaltic concrete and macadam pavements with granular base were surveyed by the panelists. The samples were randomly drawn from a large population of utility cuts on major arterials, collectors, and residential streets, all of which exhibited various levels of distress. The cuts varied in size generally from 3 feet x 3 feet to 7 feet x 10 feet.

Round 1: Initially, the research team held a series of discussions with the panelists. The panelists were familiarized with the objectives of the project. Each panelist was given a Distress Manual, a set of blank evaluation forms and a list of utility cuts to be evaluated. The use of the Distress Manual and evaluation form was explained. Trial sessions were held on two typical cuts to ensure that the panelists understood the use of the distress manual and evaluation form.

During the first round, the panelists surveyed 75 cuts over a period of two months. During the distress survey, no discussion was allowed among the panelists. The first round yielded 1125 evaluation forms.

Round 2: The information obtained during Round 1 was inputed into a database and analyzed. A large deviation in the identification and severity of the distresses as well as in the overall condition of the utility cuts was found at most of the locations. A second series of meetings was held and a statistical summary of the results for each cut was handed to the panelists. They were specifically told to refer to the summary and appropriately revise their opinion only if they felt it was necessary. The panelists re-visited all 75 cuts.

Round 3: When the results of Round 2 were tabulated, it was found that the panelists still differed in some aspects of evaluation of the utility cuts. In particular, there were 26 cuts on which there seemed to be some difference of opinion among eight panelists. Only these eight panelists and 26 cuts were included in Round 3 of the survey. No further round of survey was performed since the results indicated that there may not be any improvement to be of practical significance. Table 5.1 shows the final distribution of sample for different conditions of the utility cuts.

The overall condition given by the panelist for each cut is an aggregate measure of individual distresses which will be called the Utility Cut Condition Index (UCCI) in the following discussions. The data collected by the Delphi Method was used to develop a neural network for predicting UCCI.

Development of Neural Network Model

In recent years, artificial neural networks (ANNs) have been gaining wide applications in business and industry. In many instances, ANNs have been found to provide better results than the conventional modeling techniques, particularly if the relationships among the variables of interest are complex. There are several advantages in using a neural network for predicting UCCI based on the subjective views of human experts. For instance, the deduct point method used for highway pavement sections to convert word ratings into numerical values makes several assumptions on distress weighing factors. A neural network can use word ratings to develop a rating index without the need for such assumptions. In this study, as explained in the following paragraphs, the neural network derived expertise from examples of the distress survey and was trained to solve problems of similar nature in the future. The back-propagation method (5.12) was used to develop the neural network consisting of an input layer, an output layer and a hidden layer (Figure 5.2).

Data Pre-processing and Training the Neural Network

As mentioned before, the Delphi Method was used to collect data on the conditions of utility cuts. The database was initially prepared to contain information on the types and severity of distresses in each cut and its vicinity, and the overall condition of the cut. The information on surface profile and recommended action was not used in the development of the neural network.

Before a neural network could be developed, pre-processing of the data was necessary since neural networks can not recognize categorical information such as low, moderate or high distresses. A computer program was written to convert the categorical information on distress into numerical codes as follows:

No distress	(0,0)
Low severity	(0,1)

Moderate severity	(1,0)
High severity	(1,1)

The observations were classified into ten groups, based on UCCI ranging between 1 and 100. For example, an UCCI of 100 represents an utility cut with absolutely no distress.

To develop a neural network, two kinds of data are required: training data and testing data. A network needs to be trained so that an application of a set of inputs can produce a desired set of outputs. The testing data are used to check the accuracy of the developed neural network. The original data, consisting of 1032 observations, was separated into two parts: 709 observations or 69 percent of the total sample for training, and the remaining 323 observations or 31 percent for testing. The selection of the observations for the training and testing data sets were done randomly within each UCCI group.

A software called NeuralWorks Professional II/Plus (5.12) was used to develop the neural network described in this paper. There were 30 processing elements (PEs) in the input layer to represent nine types of distresses in the cut and six in the vicinity. The hidden layer consisted of ten processing elements. The output layer had only one processing element, that is, one UCCI for each utility cut. In this study, the sigmoid function (5.13) was chosen to be the transfer function. Although other transfer functions such as hyperbolic tangent or sine were also tried, sigmoid transfer function was found to allow the Root Mean Square (RMS) converge most quickly.

The selection of a set of proper learning coefficients and momentum value is important, since they are sensitive and critical to the network learning. After a few trial runs, the initial learning coefficients were set as 0.3 for the hidden layer and 0.2 for the output layer and the momentum was 0.8. These values were gradually reduced for higher number of training iterations as shown in

Table 5.2.

<u>Neural Network Testing</u>

The neural network was tested with the testing data. A comparison of the actual UCCI with the predicted UCCI showed that the average absolute error (actual UCCI minus predicted UCCI) was 6.5 and the average relative error ([actual UCCI minus predicted UCCI]/ actual UCCI) was 4.0 percent. When the output band was set to plus or minus 12, the neural network was found to correctly predict 92 percent of the outputs. A graphical plot of the actual and predicted UCCIs and the output band is shown in Figure 5.3.

Discussion

This study utilized the neural network technique to develop the relationship between observed distresses and rating index for utility cuts. Although the Delphi Method was used to reduce variation in the condition evaluation of utility cuts, there are still "noises" in the data since the inspectors and engineers did not always agree on the type and severity of distresses and the overall rating of the utility cuts. The neural network showed that a larger discrepancy between the predicted and actual outputs existed when the UCCIs were either very large or very small, for example, when UCCI was greater than 90 or lower than 10. It is believed that these errors were caused due to the small sample size within these groups.

A question might arise regarding what threshold value of UCCI one should use to determine when some maintenance action must be taken on a utility cut. In the case of highway pavements, many state agencies have used a value of 50 to 65, on a scale of 0 to 100, as the threshold value for maintenance management. When the pavement condition reaches the chosen value, maintenance action is taken. The same reasoning also should apply for utility cuts. In the present study, utility cuts have been found to have ratings that were less than 10, indicating that the existing threshold values for highway pavements may not be suitable for utility cuts. It is suggested that a threshold value for utility cuts be established in the future.

Conclusions

A periodic evaluation of the conditions of utility cuts is essential for better management of city street pavements. However, none of the existing pavement condition indicators are suitable for defining conditions of utility cuts, as the performance characteristics of utility cuts differ widely from those of longer highway pavement sections. This study is a first attempt to evaluate distresses in and around utility cuts. It utilizes a rational procedure to develop a rating index for utility cuts.

The Distress Manual for utility cuts is a valuable tool for city engineers and inspectors engaged in the evaluation of utility cuts. The Delphi Method assists in narrowing the variations of opinions among panel members and provides an advantage in training city engineers and inspectors to make condition evaluations of utility cuts on a uniform basis.

The neural network for predicting Utility Cut Condition Index (UCCI) was developed by using a large amount of field data. The model has been trained and tested for its accuracy. The UCCI predicted by the neural network can be used as a management tool for identifying conditions of utility cuts in a city and assigning priorities for their maintenance.

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TABLE 5.1. Final Results of Distress Survey

Surface Profile					
	1-10	11-20	21-30	31-40	41-50
	17	50	60	120	180
	51-60	61-70	71-80	81-90	91-100
	173	231	197	84	13

Distresses	Cut			Vicinity		
	L	M	H	L	M	H
Alligator Cracking (A/J)	155	227	224	81	143	60
Edge Cracking (B/K)	222	270	147	96	57	23
Transverse Cracking (C/L)	147	206	95	232	415	70
Potholes (D/M)	155	105	61	32	13	4
Rutting (E/N)	319	172	93	142	61	11
Ravelling & Weathering (F)	476	297	145			
Drop off (G/O)	389	148	57	16	12	3
Edge Separation (H)	527	272	103			
Corner Breaks (I)	228	137	103			

Overall Condition					
	1-10	11-20	21-30	31-40	41-50
	28	74	101	153	132
	51-60	61-70	71-80	81-90	91-100
	159	109	172	95	9

Action	Do Nothing	Surf. Treat.	Overlay	Reconstruct
	288	249	139	356

TABLE 5.2. Learning Coefficient and Momentum Values

Number of Iterations	< 10000	< 20000	< 70000	< 150000
L_{coef} for Hidden Layer	0.30	0.1500	0.0375	0.00234
L_{coef} for Output Layer	0.15	0.0175	0.0188	0.00117
$M_{momentum}$	0.80	0.4000	0.1000	0.00625

City of Cincinnati

Prepared by:________________ Date of Survey:________________

Location:________________ Time of Survey:________________

Surface Profile (enter a number)	very poor	poor	fair	good	excellent
	0 - 20	21 - 40	41 - 60	61 - 80	81 - 100
⇨					

Distresses (Rate by severity. If different levels exist, rate by highest severity)	Cut			Vicinity		
	low	moderate	high	low	moderate	high
Alligator Cracking						
Edge Cracking						
Transverse Cracking						
Potholes						
Rutting						
Ravelling & Weathering						
Cut-to-Adjacent Pavement Drop-off						
Edge Separation						
Corner Breaks						

Any additional distress?

Overall condition
- very poor(0-20)
- poor(21-40)
- fair(41-60)
- good(61-80)
- excellent(81-100)

Recommended action
- do nothing
- surface treatment
- overlay
- reconstruct

Additional Remarks:

FIG. 5.1. Evaluation forms for utility cuts

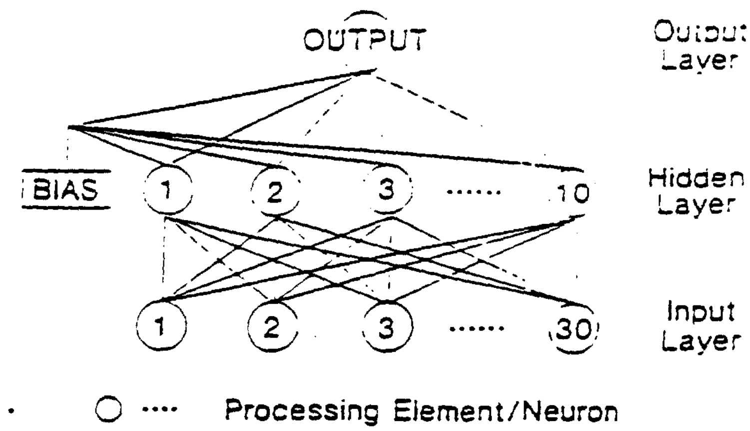

FIG. 5.2. Neural Network Structure

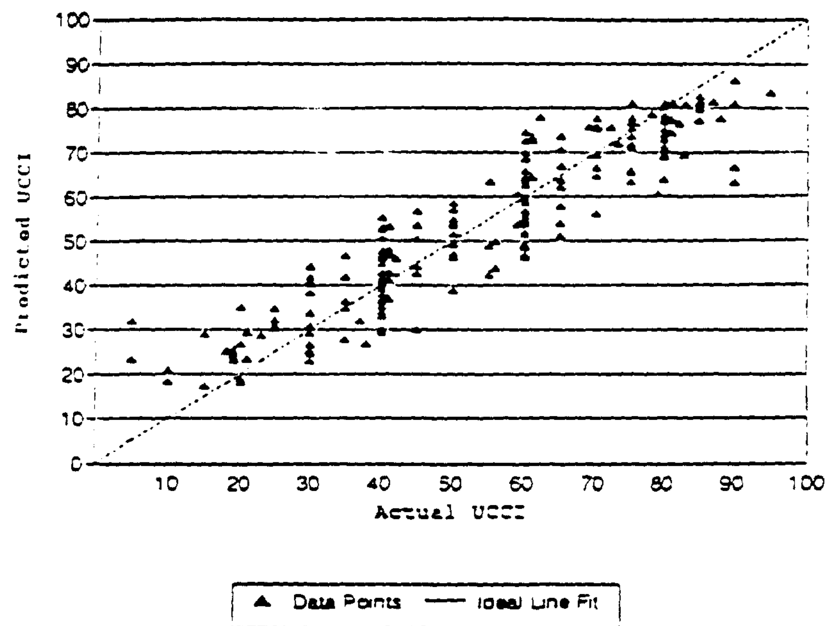

FIG. 5.3. Comparison of Predicted UCCI with Actual UCCI